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RESEARCH ARTICLE

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Analysing the capacity to respond to climate change: a framework for community-managed water services

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ABSTRACT
In this paper, we present a conceptual framework for guiding interdisciplinary research on analysing the capacity of community-managed water services to respond to disturbances from climate change. Climate change poses a serious threat to the sustainable delivery of community-managed water services in developing countries. We synthesized key concepts from the latest research on vulnerability and resilience theories into a shared framework that functions as a heuristic for the analysis of different elements of the capacity to respond to climate disturbances and how they are related to community-managed water services. Primary elements of the framework include conceptualisations of the capacities to respond to specific hazards (e.g. through risk management and knowledge of thresholds) and to disturbances in general (e.g. through agency, social structure, and adaptive management practices), the potential for capacity to be differentiated across scales, and the social and biophysical system characteristics that influence capacity to respond to climate change. We describe how each these elements relate to sustaining community-managed water services against climate change throughout the paper. We also discuss subjective choices (temporal frame, system boundaries, scale of inquiry, and desired forms of capacity) that analysts must make when considering how capacity to respond to climate change is analysed.

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Climate change; community; resilience; vulnerability; water service

Introduction

Climate change poses a serious threat to the delivery of adequate water services around the world (Howard, Calow, Macdonald, & Bartram, 2016). Changes in the frequency, intensity, duration, and distribution of rainfall, temperature, and extreme weather events, along with sea-level rise, can directly disrupt water services in a multitude of ways including increased contamination events; destruction of infrastructure; groundwater salinization; diminished water resource availability; increased water demand; and increasingly unpredictable climate conditions (Batchelor, Smits, & James, 2011; Bonsor, MacDonald, & Calow, 2010; Luh, Royster, Sebastian, Ojomo, & Bartram, 2017). Consequently, climate change threatens to increase incidences of water-related diseases, exacerbate water insecurity, and undermine achievement of Sustainable Development Goal water targets with burdens falling disproportionally on disadvantaged groups (Howard et al., 2016; Hutton & Chase, 2016; OHCHR, n.d.)

Although water services are delivered in many different ways, the threat that climate change poses to community-managed water services in developing countries requires particular attention. In this paper, we define community-managed water services as the interlinked water resource, infrastructure, and social systems that facilitate water access for domestic purposes and are managed collectively by a community. Special attention is needed to such services because it is estimated that, by 2030, 62% and 41% of people in low- and middle-income countries, respectively will still live in rural areas (UN-DESA, 2014) where community management is the most common approach to water service delivery (Howard et al., 2016). To prepare for the (mostly adverse) effects of climate change on community-managed water services (Batchelor et al., 2011; Howard et al., 2010), researchers and other stakeholders require an understanding of the different ways in which these services can be sustained against climate disturbances.

Vulnerability and resilience have emerged as different, but related, and highly influential bodies of theory-practice for guiding policy on addressing climate change. In particular, they each offer valuable insights on how linked social-ecological (also known as coupled human-environment) systems (SESs) are affected by and respond to disturbances from climate change (Adger, 2006; Turner, 2010). Vulnerability may be broadly understood as a 'propensity or predisposition to be adversely affected' (IPCC, 2014), although more nuanced interpretations vary as discussed in the following section. Resilience similarly has a range of interpretations, but theory about the resilience of SESs is most frequently evoked in the climate change literature (Bahadur, Ibrahim, & Tanner, 2013). A common definition of SES resilience is 'the capacity of a system to absorb disturbance and reorganize so as to retain essentially the same function, structure, and feedbacks – to have the same identity' (Walker & Salt, 2012). Despite the high levels of policy attention and thought given to vulnerability and resilience theories in other sectors, water, sanitation, and hygiene (WASH) researchers have not yet fully engaged with the breadth of the vulnerability and resilience knowledge bases (Kohlitz, Chong, & Willetts, 2017).

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Although the application of either the vulnerability or resilience approach to conceptualising how community-managed water services experience climate change has potential to generate valuable insights, we assert that their joint application may be even more beneficial. Several authors remark that vulnerability and resilience approaches are complementary because they tend to focus on different spatial scales of analysis, timeframes, and domains (i.e. social for vulnerability and ecological for resilience) which helps to address each other's limitations (Eakin & Luers, 2006; Miller et al., 2010; Turner, 2010). Other authors warn that each approach involves implicit tradeoffs in policy formulation and policy outcomes because the objectives of approach can draw attention away from the objectives of the other (Eakin, Tompkins, Nelson, & Anderies, 2009). Conceptually combining the approaches facilitates the identification of synergies and tradeoffs because it allows analysts to examine fundamental commonalities and differences between different worldviews. For example, in the context of WASH services, looking at the climate change challenge with a combined lens can help stakeholders negotiate decisions about whether to focus adaptation efforts on WASH infrastructure, water resources, or equitable access, or about the extent to which adaptation efforts should invest in meeting people's WASH needs now versus preparing future generations for worsening climate impacts (Kohlitz et al., 2017).

The purpose of this paper is to present a conceptual framework for guiding interdisciplinary research on analysing the capacity of community-managed water services to respond to climate disturbances to sustain water access. The framework is a synthesis of vulnerability and resilience concepts that describe the capacity of a system to respond to disturbances; a key point of convergence between vulnerability and resilience research (Adger, 2006).

A conceptual framework is useful because it provides a 'metatheoretical language' (McGinnis & Ostrom, 2014) that enables a shared understanding of a situation before action is taken. In reference to incorporating social theories into SES resilience thinking, Fabinyi, Evans, and Foale (2014) claim that interdisciplinary dialogue is a more pragmatic and realistic way of joining perspectives than conceptual frameworks. However, we believe that the two drive, not detract from, each other. Further, whether consciously considered or not, all adaptation recommendations for building capacity to respond to climate disturbances are based on assumptions of how capacity is created in the first place. Conceptual frameworks help make these assumptions explicit so they can be more easily analysed, critiqued, and justified.

This paper is structured to begin with an overview and our commentary on existing frameworks that aim to integrate theories of vulnerability and resilience. Following this, we present our conceptual framework and provide illustrative examples of concepts in the context of community-managed water services. Next, we discuss areas within the framework where analytical choices must be made that have significant implications for how a capacity assessment is carried out. We conclude with thoughts on the needs for further research and situational awareness.

Integrated conceptual frameworks

In this section, we present an overview of examples of prior conceptual frameworks that aim to integrate different vulnerability and resilience theories. This is not an exhaustive review of frameworks in the literature but instead a review of frameworks that are influential seminal works in their field or reflect the latest thinking on these theories. We comment on their contributions and limitations to set the stage for our framework. We first present four frameworks that integrate different vulnerability theories, then four frameworks that integrate vulnerability and resilience theories. All of the frameworks refer to some form of capacity, or lack thereof, to respond to disturbances.

Integration of different vulnerability theories

Two broad research traditions have predominated in vulnerability studies. One interprets vulnerability to climate change in terms of the amount of potential damage that a particular climate disturbance can cause to a system, and the other interprets it as a state of the system that already exists before a disturbance is encountered (Brooks, 2003). The former has been called outcome vulnerability and the latter contextual vulnerability (O'Brien, Eriksen, Nygaard, & Schjolden, 2007). Some vulnerability analyses, as demonstrated below, aim to integrate these two theories to consider an 'overall' vulnerability.

Two early and influential frameworks that conceptualised an integration of these two vulnerability theories are the 'pressure and release' model and the 'hazard of place' model. The pressure and release model developed by Blaikie, Cannon, Davis, and Wisner (1994) conceives vulnerability as being produced by economic, social, and political processes (called 'root causes' and 'dynamic pressures') that create conditions for a system that are unsafe with respect to a particular hazard. Thus, the model views vulnerability as a product of both exposures to a hazard and social pressures that influence people's capacity to respond to disturbances (Adger, 2006). The hazard of place model developed by Cutter (1996) similarly views overall vulnerability (termed 'place vulnerability') as a combination of potential exposure to a biophysical risk and a social predisposition to susceptibility to environmental threats (Cutter, 1996). These models were important early contributions to modern vulnerability thinking but are limited in that they weakly consider the interlinkages between human and environmental systems and provide little detail on the structure of vulnerability causality (Cutter et al., 2008; Turner et al., 2003).

Later integrated frameworks reflected a development in terminology and causality. For example, Füssel and Klein's (2006) framework for a 'second-generation vulnerability assessment' conceives vulnerability as being jointly produced by biophysical climactic stimuli and non-climactic drivers as do its predecessors. But moreover, the authors explicate causality through expressing vulnerability as a function of exposure, sensitivity, and adaptive capacity. They define exposure as 'the nature and degree to which a system is exposed to significant climatic variations' and sensitivity as 'the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli'. Meanwhile, instead of a negative term indicating a social predisposition to harm, the term adaptive capacity is used to mean the capacity of the social system to adjust to avoid harm or take advantage of opportunities from climate change (Füssel & Klein, 2006). The framework also acknowledges that vulnerability needs to be assessed at different scales (e.g. vulnerability for a country may appear low but be high for certain sub-groups within it).

The second-generation vulnerability framework is still limited in two ways. First, although it may recognize that the vulnerable system can be an integrated social-biophysical system (Füssel, 2007), there is still little recognition of the complex interactions between humans and environmental systems that influence the capacity to respond to climate disturbances. Second, there is no analytic disaggregation of the adaptive capacity concept. As a result, some vulnerability authors use the term adaptive capacity to refer to the capacity to respond to specific anticipated hazards (Brooks, Adger, & Kelly, 2005) while others use it to refer to the capacity to respond to changing shocks and trends in general (Jones, Ludi, & Levine, 2010). Both forms of adaptive capacity can be assessed at the same time but the framework provides no guidance on the delineation or interactions between the two forms.

More recently, effort has been made to reconcile different interpretations of adaptive capacity by explicitly distinguishing them and studying their relationships. Authors distinguish the capacity to adapt to specific anticipated hazards from the capacity to adapt to disturbances in general by labelling them specific capacity and generic capacity respectively (Eakin, Lemos, & Nelson, 2014; Lemos et al., 2013; Nelson, 2011). Eakin et al. (2014) propose a framework for analysing the relationships between the capacities. In some instances, the capacities have positive feedback relationships such as when both capacities are low and poverty traps are created. Their framework also considers interactions between capacities at different scales. For example, in countries that have high generic capacity, individuals may have low specific capacity if they expect national authorities to look after them when a specific hazard is experienced (Eakin et al., 2014). As with the other vulnerability frameworks, this framework is socially focused and pays little attention to the role of environmental systems in building capacity to respond to disturbances.

Thus, these vulnerability frameworks have made valuable contributions toward explicating how physical disturbances are experienced by a system and the different capacities of social groups to respond to disturbances. However, to-date, they have had limited engagement with how environmental factors influence this capacity. This is significant with respect to community-managed water services because climate change threatens to disrupt water ecosystem services that are vital for the ongoing delivery of water service delivery.

Integration of vulnerability and resilience

Although authors state that vulnerability and resilience approaches are complementary (Adger, 2006; Miller et al., 2010; Turner, 2010), few attempts have been made to integrate them in a conceptual framework. In this section, we present four integrated vulnerability-resilience frameworks and discuss their contributions.

Two of the reviewed frameworks conceptualize resilience broadly as a collection of capacities for responding to disturbances, and consider this as a subset of vulnerability. For example, the framework by Turner et al. (2003) shows vulnerability as a function of the system's exposure to a hazard, its sensitivity, and its resilience. Resilience is determined by the system's capacities to cope, adjust, and adapt to hazards, and the resulting impacts (Turner et al., 2003). Similarly, the framework by Birkmann et al. (2013) shows vulnerability as a function of exposure, susceptibility, and resilience. Here, resilience is determined by the system's capacities to anticipate, cope with, and recover from hazards (Birkmann et al., 2013). In both these frameworks, an increase in resilience directly results in a decrease in vulnerability. They are similar in structure to the second-generation vulnerability framework described above but substitute adaptive capacity with resilience.

Unlike the vulnerability frameworks, the framework by Turner et al. (2003) asserts that interactions between social systems and ecosystems influence the capacity of the SES to respond to disturbances. Drawing on SES resilience theory, the authors conceive the system of interest as comprising social and environmental components (termed 'human conditions' and 'environmental conditions') that interact to influence the SES's resilience. However, little detail is provided on how the human and environmental conditions influence resilience.

The other two reviewed vulnerability-resilience frameworks interpret resilience as the capacity of an SES to absorb disturbances and maintain its key structure and functions. The framework by Chapin, Folke, and Kofinas (2009) views vulnerability and resilience as separate concepts but bridged by the concept of adaptive capacity. Vulnerability is defined as 'the degree to which a system is likely to experience harm due to exposure to a specified hazard or stress' (Chapin et al., 2009). Adaptive capacity is said to contribute to both reducing vulnerability and strengthening resilience. Thus, adaptive capacity is a capacity to respond to both specific hazards (reduce vulnerability) and disturbances in general (strengthen resilience). However, the framework does not disaggregate the adaptive capacity concept such that the capacities to respond to specific hazards and disturbances, in general, can be analysed separately. Similarly, the framework by Maru, Stafford Smith, Sparrow, Pinho, and Dube (2014) also views vulnerability and resilience as separate concepts that are linked together by adaptive capacity. Although unlike Chapin et al. (2009), a contextual interpretation of vulnerability is followed so the capacity to respond to specific hazards is not conceptualized in the framework.

The absence of a disaggregated conceptualization of the capacities to respond to specific hazards and disturbances in general in the vulnerability-resilience frameworks is significant because it overlooks the potential for either capacity to create different outcomes. Empirical evidence is emerging that communities require both a capacity to address specific climate-related risks and a capacity to respond to more general social, economic, political and ecologoical stressors to successfully adapt to climate effects (Lemos, Lo, Nelson, Eakin, & Bedran-

Table 1. Analytical functions of selected conceptual frameworks.

	Füssel and Klein (2006)	Eakin et al. (2014)	Turner et al. (2003)	Birkmann et al. (2013)	Chapin et al. (2009)	Maru et al. (2014)
Distinguishes between capacity to respond to specific disturbances and capacity to respond to disturbances in general		✓				
Analyses interactions between specific and general capacities		✓				
Acknowledges that capacities to respond are differentiated across system & sub-system scales	✓	✓	✓	✓	✓	✓
Analyses interactions between capacities at system & sub-system scales		✓				
Considers interactions between ecosystems and humans in influencing capacities to respond			✓		✓	✓

Martins, 2016). A more nuanced conceptualization of the capacity to respond is needed to address the particular challenges of known hazards and disturbances that come with uncertainty.

Summary

In summary, the integrated vulnerability and vulnerability-resilience frameworks make important contributions toward analysing how systems respond to climate change disturbances that can be valuably synthesized into a common framework. Table 1 shows key analytical functions advanced by the frameworks developed since 2000 that we reviewed. Gaps in analytical functions of one framework can be seen to be covered by at least one other framework (see Table 1). Furthermore, although not reviewed in detail here, each framework provides varying levels of detail on concepts that characterize capacity to respond to climate change disturbances. These concepts, and others from the wider vulnerability and resilience literature, can also be synthesized to provide more depth to the analytical functions.

The framework

In this section, we build on the contributions of prior frameworks and draw on recent vulnerability and resilience literature to propose our framework for analysing the capacity of community-managed water services to respond to climate disturbances to sustain water access (Figure 1) It comprises constituent concepts from theories of vulnerability and resilience that we have reassembled to guide a coherent and novel way of assessing a situation (Bergmann et al., 2012). In particular, the framework acts as a heuristic that guides researchers and other stakeholders involved in planning or assessing a community-managed water service to consider different ways in which the service can be sustained against climate change impacts.

We present the framework by first describing its purpose and its delimitations. Next, we present the framework element-by-element as follows: (i) describing the system of interest; (ii) assessing social and biophysical characteristics that influence specific and general capacities to respond to disturbances; (iii) assessing interactions between specific and general capacities; (iv) assessing the capacities at different scales; and (v) assessing the interaction of capacities across scales within the system. We provide illustrative examples in the context of community-managed water services throughout the section.

Purpose of the framework

The overall purpose of the framework is to guide interdisciplinary research on analysing the capacity of community-managed water services to sustain access to water against climate disturbances. The value of the framework is that it (i) sensitizes users to the different elements that contribute to the capacity to respond to disturbances and (ii) facilitates interdisciplinary research by framing disparate disciplinary concepts together and by drawing out their relationships.

We intend the framework to be a heuristic for bridging vulnerability and resilience approaches at a conceptual level and, as such, it does not obsolete vulnerability or resilience theories. There is still a need for in-depth disciplinary knowledge to elaborate and operationalize the social and ecological concepts presented here. We also do not intend the framework to be prescriptive. Instead, it informs analysts of where important analytical choices need to be made and encourages critical thought about the implications of those choices.

Delimitations

We designed the framework with three key delimitations in mind. First, it was intended for community-managed water services in a developing country setting, although it may have application to other services that rely on natural resources. Second, the framework can accommodate systems at any scale, but it is primarily conceptualized at a local level. Third, the framework characterizes how capacity to respond to disturbances is constructed, but it does not seek to characterize how adaptation actions materialize. We refer readers to Turner et al. (2003), Cutter et al. (2008), and Birkmann et al. (2013) for examples of frameworks that characterize adaptations and responses. Lastly, our definition of capacity to respond, discussed in the following sections, does not include the capacity to transform the system into something fundamentally different (Béné, Newsham, Davies, Ulrichs, & Godfrey-Wood, 2014).

Describing the system

We start with the boundaries of the system which are represented in the framework by the box on the left. The system boundaries determine what is considered to be part of the system and what is considered to be an external influence. These boundaries are subjective, as discussed further elsewhere in this paper, but should take into consideration both social and biophysical dimensions of the system. For example, an analyst

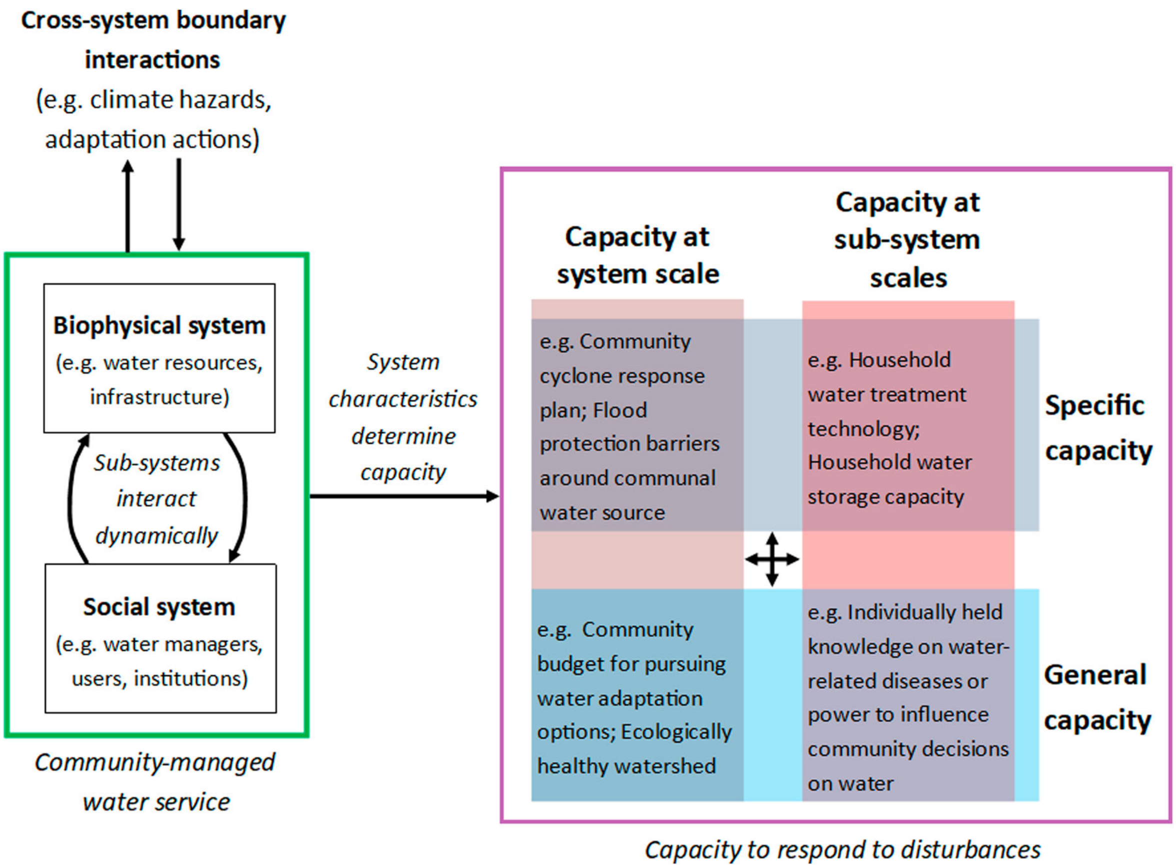

Figure 1. Conceptual framework for the capacity of a system to respond to disturbances.

could choose to align the boundaries with the land traditionally owned by a community or along an entire water catchment.

Within the boundaries is the community-managed water service being analysed which is represented as an SES. An SES is a system that comprises social/human and ecological/environmental sub-systems that interact dynamically. Community-managed water services can be viewed as comprising systems of water resources, infrastructure, and social systems that facilitate water access and demand (Moriarty, Batchelor, Laban, & Fahmy, 2010). We group water infrastructure with water resources and associated ecosystems under the label 'biophysical system'. Water infrastructure and water resources have significantly different functions, but, as will be demonstrated, many climate change vulnerability and resilience concepts have similar applicability to them. The social system comprises actors (e.g. water users and managers) and formal and informal governance institutions. Although it is useful to distinguish social and biophysical systems for analytical purposes, it must be noted that they are inextricably linked to each other. Changes in the sub-systems that make up a water service (e.g. water resources and different social organizations) inevitably have effects on other sub-systems, often with resulting feedback loops (Neely & Walters, 2016). The nature of the water service system is continuously changing due to dynamic endogenous processes (see Neely (2015) for examples and discussion) and cross-system boundary interactions (Carpenter, Walker, Anderies, & Abel, 2001; Smit & Wandel, 2006). An example of a cross-system boundary interaction may be an international non-governmental organization visiting a community to provide training on water management.

The box on the right represents the overall capacity of the system to respond to disturbances. Capacity to respond encompasses multiple concepts as will be discussed. Responses include adaptations, adjustments, coping actions, or simply resisting change. The capacity to respond may or may not be realized. Emerging research on adaptive capacity indicates that psycho-social factors influence how capacity is translated into actual adaptation outcomes (Mortreux & Barnett, 2017). The analysis of translating capacity into action is beyond the scope of our framework.

The social and biophysical characteristics of the system determine its capacity to respond to disturbances. Actors within the system may change their attitudes, behaviours, and beliefs based on their perceptions of the levels of, nature of, or changes in capacity to respond. This can cause a change in social characteristics, or cause actors to modify the biophysical system characteristics, which feeds back to affect the capacities.

The framework views the overall capacity to respond as being driven by two forms of capacity: specific and general. This distinction between capacities is found in both the vulnerability and resilience literature. Vulnerability scholars distinguish between specific adaptive capacity (the capacity to respond to particular risks) and generic adaptive capacity (the capacity to respond to a range of stressors) (Eakin et al., 2014; Lemos et al., 2013; Nelson, 2011). Similarly, the resilience field distinguishes between specified resilience (the resilience of a particular part of the system to a specific threat) and general resilience (the resilience of all aspects of a system to unspecified disturbances) (Folke et al., 2010; Miller et al., 2010; Walker & Salt, 2012). We group characteristics that determine specific adaptive capacity and specified resilience under specific capacity and characteristics that determine generic adaptive capacity and general resilience under general capacity.

Specific capacity

Specific capacity in the framework refers to the capacity of the system to respond specifically to known hazards. Gauging the hazards' risk levels is a first step toward assessing specific capacity. This can be done by first predicting how climate change will affect the frequency, magnitude, duration, or spatial distribution of climate hazards to which the water supply is exposed (e.g. an intensification of cyclones or a reduction in total annual rainfall). The hazards can also be ranked based on their likelihood of affecting the water supply (e.g. sea level rise may be deemed unlikely to affect water supplies located far away from the coast). These characteristics can be predicted through climate projections (Howard et al., 2010), although projections continue to be limited by uncertainty at local scales (Knutti & Sedláček, 2013). Risk level is further gauged through an assessment of the degree to which the hazards can potentially disrupt water services (e.g. a reduction in rainfall is potentially highly disruptive to rainwater harvesting systems). The potential degree of severity may be assessed based on prior experience with hazards, expert opinion, or scenario building (Batchelor et al., 2011; Howard et al., 2010; Luh et al., 2017) Finally, risk level can be further analysed by considering the ability of the social system to take offset deleterious effects of climate impacts by reducing the exposure or sensitivity of parts of the water system (e.g. by analysing whether the community is able raise the parapets of wells and install to reduce sensitivity to flooding).

One way that specific capacity is influenced is through characteristics of the biophysical system that allow it to withstand the impacts of the identified hazard. These characteristics can be assessed in terms of the biophysical system's thresholds – the limits that certain variables can reach until functioning of the system dramatically changes (Chapin et al., 2009). Thresholds can pertain to physical parameters of the water system (e.g. water quantity, quality, or continuity (Luh et al., 2017)) or ecological parameters (e.g. soil phosphorous content which contributes to the stabilization of lakes in a clear-water state or a turbid-water state (Carpenter et al., 2001)). The higher the degree of disturbance the system can experience without crossing a threshold, the more resilient it is. For example, one way to assess a rainwater harvesting systems's specific capacity to withstand periods with no precipitation could be to measure the volume of water stored in the system once precipitation stops (i.e. measuring where the water quantity threshold lies) and how many days without precipitation can be experienced before the water source is depleted (i.e. measuring how rapidly the threshold will be reached).

Another way that specific capacity is influenced is through the capacity of the social system to anticipate, plan for, and react to specific hazards. Ways in which this is built include awareness about specific possible effects of climate change, the presence of early warning systems (e.g. mobile phones and radios for receiving hazard alerts), and possession of human resources (e.g. skills, knowledge, and tools) needed to implement risk management strategies. Regarding water services, risk management strategies include modified Water Safety Plans which aim to identify and assess hazards, risks, and existing control measures to safeguard water services against impacts of climate variability and change (WHO, 2017). The threshold concept may also be relevant here. For example, analysts may ask at what point does a water service fail due to users rejecting the water based on aesthetic reasons? However, thresholds in social systems are relatively difficult to measure.

General capacity

General capacity refers to the capacity of the system to respond to uncertainty and disturbances in general. It is determined by system characteristics that promote flexibility, innovation, and freedom of choice such that the system has multiple ways of responding to a range of different disturbances. This contrasts with a specific capacity which is determined by characteristics that are assessed as relevant with respect to a specific hazard.

The biophysical system influences general capacity through its structure. Research shows that functional redundancy and response diversity within water ecosystems gives them an enhanced ability to absorb disturbances and continue functioning because ecosystem components can compensate for one another (Biggs, Schlüter, & Schoon, 2015). Likewise, diversification of water supplies (Elliot, Armstrong, Lobuglio, & Bartram, 2011; Kuruppu, 2009) and increased redundancy through an expanded number of discrete water supplies (Boelee et al., 2013; MacDonald, Calow, MacDonald, Darling, & Dochartaigh, 2009) provide 'insurance' against disturbances through more options for accessing water. Connectivity, the degree and way in which system components are connected with another, also influences capacity to respond by facilitating recovery or by propagating disturbances (Biggs et al., 2015). Decentralization of water infrastructure such that it is less likely that one disturbance causes all water services to fail (Howard & Bartram, 2010) reflects the connectivity principle. The biophysical system also influences general capacity through the presence of so-called no-regrets adaptations. These are adaptations that are believed to be beneficial under any climate scenario. It is argued that groundwater recharge, stormwater capture and control, and water conservation measures are no-regrets features of a water service (Elliot et al., 2011).

Characteristics of social systems also influence general capacity. Within the vulnerability literature, a wide array of characteristics is identified as influencing generic adaptive capacity (see Mortreux and Barnett (2017), and Warrick, Aalbersberg, Dumaru, McNaught, and Teperman (2017) for reviews). We organise these characteristics using the Empowerment Framework developed by Narayan (2005) (Figure 2).

Agency and opportunity structure empower people to respond to all types of disturbances through expansion of their freedom of choice and action (Narayan, 2005). Agency is built through material assets (physical and financial) that

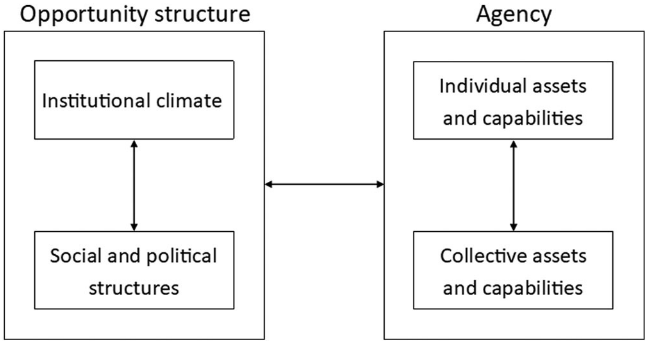

Figure 2. The Empowerment Framework. Adapted from Narayan (2005).

are individually or collectively owned and capabilities which enable individuals or groups to access and use their assets in different ways (Narayan, 2005). Types of capabilities often cited in the adaptive capacity literature include social capital (e.g. social networks and relationships), human capital (e.g. education and health), and collective action (e.g. activity coordination) (Warrick et al., 2017). Assets and capabilities have long been believed to enable people to more effectively respond to shocks and stresses in general (Chambers & Conway, 1991, p. 11; Jones et al., 2010). Concerning water services, assets could include the physical tools that people use to make repairs to a water supply or a community budget for pursuing climate change adaptations. Capabilities could include knowledge of water-related disease transmission or community processes for discussing water issues.

The opportunity structure represents the institutions and socio-political structures that facilitate or impede the realization of agency. This includes informal and formal institutions and structures such as gender relations, societal norms of power-sharing, local regulations, and constitutional law. An opportunity structure that enhances people's agency will improve their capacity to respond to disturbances in general. For example, human rights dimensions of equitable distribution of resources and participation in decision-making, transparency in decision-making, and accountability of decision-makers influence the capacity of people to adapt to climate change (Ensor, Park, Hoddy, & Ratner, 2015). The framework on the human rights to water and sanitation offers insights on how these dimensions influence the capacity of water providers and users to adapt to climate change (OHCHR, n.d., pp. 25–50).

Resource management and governance regimes are another critical part of the opportunity structure that is especially relevant for water services. Resource management and governance regimes that promote learning, participation, innovation, fairness, and risk sharing are structures that can be beneficial for both human agency and the ecological resilience of natural resources (Biggs et al., 2015; Jones et al., 2010; Lemos et al., 2013; Pahl-Wostl, 2009). Concerning water governance, it is argued that polycentric governance regimes that 'combine the distribution of power and authority with effective coordination among various centers and across spatial levels' tend to have higher adaptive capacity than other regimes (Pahl-Wostl & Knieper, 2014). Overall, the opportunity structure of the local system of analysis will be closely tied to opportunity structures at broader scales.

Interactions between specific and general capacity

Specific capacity and general capacity are closely linked to each other. In some ways, they can be synergistic. It is argued that a minimum level of generic capacity may be necessary for a household to build specific capacity (Lemos et al., 2013; Lemos et al., 2016). For example, a community may desire to protect a spring source from flooding but require access to markets to acquire building materials to do so. Building specific capacity can also enable generic capacity. For example, if a household protects its water supply from contamination during floods, a resultant improved overall health of the family may enable them to better cope with other disturbances. Consequently, building one capacity sometimes also serves to build the other such that they are mutually reinforcing (Eakin et al., 2014).

In other ways, specific and general capacity can be oppositional. Too much focus on specific capacity can weaken general capacity when resources spent on making one system part resilient to a single type of disturbance causes neglect of the rest of the system (Folke et al., 2010; Walker et al., 2006). For example, a community that invests in developing a pumping system to maintain water continuity during droughts may require higher user fees to cover maintenance costs. Higher user fees, in turn, may burden poor families and reduce their general capacity to respond to other disturbances. Conversely, building general capacity alone, such as through poverty reduction, may be inadequate for preparing communities and individuals to respond to specific hazards (Nelson, Lemos, Eakin, & Lo, 2016). The precise ways in which specific and general capacity may strengthen or undermine each another across different settings are difficult to predict (Eakin et al., 2014). Therefore, it is important to make efforts to examine these interactions on a case-by-case basis.

Scale of capacity

Specific and general capacity can be assessed at the scale of the entire system, as defined by the system boundaries, or at some sub-system scale so that groups can be compared. As with the system boundaries, sub-system scales are subjective. They can be defined spatially or along fluid social lines (Tschakert, 2012).

Levels of capacity can vary depending on what scales of inquiry are included in the analysis. At a system scale, capacity would be assessed in terms of the collective ability of the community to sustain water resources and services against climate disturbances. Take an example of a rural village extracting water from a spring. General capacity may appear to be high if the spring is pollution-free and surrounded by diverse vegetation, and if the community has strong social bonds for collectively maintaining shared assets that sustainably extract water. Specific capacity may also appear high if the community has a preparedness plan for protecting the water supply when a natural disaster is expected.

However, a focus at the whole-of-system scale can overlook differentiated capacity at smaller, embedded scales (Ingalls & Stedman, 2016). Within a community, levels of vulnerability and resilience often differ across social groups (Béné et al., 2014; O'Brien et al., 2007) and are relational. For example, women within the community may have relatively less general capacity if they are excluded from decision-making processes on the maintenance of water resources and assets. Poor families may have relatively less specific capacity to prepare for a disaster if they have fewer resources for storing and treating water at home. Likewise, high capacity of individual parts of the system does not necessarily signify high capacity throughout the entire system.

Interaction of capacity between system and sub-system scales

Capacities at the different scales can also influence each another. Localized changes in vulnerability and resilience can positively or negatively affect those at broader scales (Chelleri, Minucci, & Skrimizea, 2016; Eakin & Wehbe, 2009; Folke et al., 2010). For example, in positive terms, a single community member that receives water management training could take their knowledge to a community water committee to promote appropriate climate change adaptations. In negative terms, a household could leverage their land rights during times of climate-driven water scarcity to secure a water source for their family to the exclusion of others in the community. Conversely, vulnerability and resilience at localized scales are influenced by those of systems in which they are nested (Folke, 2006; Ribot, 2011). For example, the specific capacity of individual households to prepare for disasters is influenced by the capacity of authorities at broader scales to detect impending disasters and send out warnings. As with the interaction between specific and general capacity, how capacities at different scales interact with each other across different settings is difficult to predict and must be assessed on a case-by-case basis.

Summary

In summary, community-managed water services can be considered SESs that comprise dynamically interacting biophysical and social systems. Characteristics of the social and biophysical systems, which arise and continuously change due to endogenous processes and cross-system boundary interactions, generate a capacity to respond to climate disturbances. Perceptions of this capacity can, in turn, cause changes in the system's characteristics. The capacity to respond to disturbances can be disaggregated analytically into specific and general capacity. The former is a capacity to respond to specific hazards and the latter is a capacity to respond to uncertainty and disturbances in general. The capacities are possessed differentially at a system scale (i.e. a community-water resource level) and sub-system scales (e.g. individuals or groups of people). Interactions between specific and general capacity, and between capacity possessed at a system scale and sub-system scales, are context-specific.

Making analytical choices when using the framework

While we have synthesized vulnerability and resilience concepts in this framework in a coherent way, certain parts of the framework still need to be negotiated between different perspectives due to epistemological differences between the theories from which we drew. O'Brien et al. (2007) write that outcome and contextual vulnerability interpretations cannot be integrated into a common framework because they fundamentally differ in their conceptualizations of the causes and character of vulnerability. They go on to argue that prior attempts to develop integrative frameworks do not succeed in conceptually blending different theories but instead 'formalize a single interpretation' (O'Brien et al., 2007). We believe our framework goes further in identifying common concepts of interest across vulnerability and resilience theories and framing their relationships than earlier attempts. However, we agree that different epistemologies are a significant barrier to developing a shared understanding and use of any conceptual framework. Accordingly, in this section, we describe four areas where analysts must make choices about the application of the framework amongst multiple options: the temporal frame of reference, system boundaries, the scale of inquiry, and what forms of capacity are desirable.

The framework can be referred to in different temporal frames which influence how capacity to respond is analysed. Analysts must decide if capacity is being analysed with respect to the present, future, or dynamically across time (Füssel, 2007). High capacity in the present does not necessarily indicate high capacity in the future and vice versa. For example, a community that successfully operates and maintains multiple water supplies may be considered to have high capacity in the near-term but considered to have low capacity in the long-term if water extraction rates eventually exceed what the water resource can sustainably yield and no other water sources or demand management strategies are developed. In scenarios where water services are being developed within fragile ecosystems, this can be seen to create tension between sustaining water services to help the poor presently against considerations of long-term environmental sustainability. In such cases, the capacity to achieve each of these objectives should be weighed and reconciled.

Next, all system boundaries and scales of inquiry, even ones drawn along ecological features, are subjective (Ingalls & Stedman, 2016). This is significant because the choice of where to draw system boundaries has important implications for how the capacities are analysed. For example, the capacity of a community-managed water service may appear to be low if untrained community members with access to few resources and tools for water management are considered the only social actors within the boundaries of analysis. However, if supportive and well-resourced local government authorities are included within the boundaries of analysis, the capacity of the service may be considered to be higher. Similarly, the choice of a sub-system scale of inquiry can exclude certain groups. For example, one might analyse the differentiation in capacity between relatively poor and wealthy households but miss differentiations in capacity across genders. The choice of what to include within the system boundaries and scales of inquiry involves a values judgement about what is most important to consider. Explicit consideration of different perspectives in defining the units of analysis (Fabinyi et al., 2014) and what factors can be realistically controlled in a given context (Quandt, 2016) are recommended for defining boundaries and scales.

Lastly, although some levels of both specific and general capacity at both system and sub-system scales are always needed, the relative degrees to which each is required is context-specific and subjective. For example, some water users may desire a specific capacity more if they are focused on protecting expensive water assets or if a particular hazard is especially concerning. Others may desire general capacity more if they feel that community institutions discriminate against them or if ecosystem viability is highly valued. Due to reasons like these, analysts may choose to concentrate more on one form of capacity. However, it is important not to neglect other forms of capacity, which are still meaningful in any situation, and to be mindful of potential interactions between capacities. Further, stakeholders must be carefully consulted in this regard because the capacities will be valued differently between actors.

Overall, the choices highlighted in this section are best addressed by being aware of their implications and considering different perspectives. Making final analytical choices (e.g. on where to draw system boundaries) will often be difficult but should reflect the purpose of the analysis and the values of the stakeholders.

Conclusions

In this paper, we have presented a conceptual framework for guiding analyses of the capacity of community-managed water services to sustain access to water against climate disturbances in a developing country setting. Through a synthesis of vulnerability and resilience concepts into a shared framework, we have a provided a heuristic for analysts to make sense of the different elements of the capacity to respond to climate disturbances and how they are related. Our framework is not prescriptive and can be followed in different ways. As such, we have discussed the need to think critically about assumptions about the system regarding the temporal frame of reference, system boundaries, the scale of inquiry, and the most desirable forms of capacity.

The framework has potential to be drawn on by a range of stakeholders. Researchers may use it to study to what extent and how certain concepts influence the capacity of a community-managed water service to sustain water access against climate change disturbances. Further work to operationalise elements of the framework in the context of rural water services is needed before practitioners and policy-makers can use it as a tool to guide their work. In its current state, practitioners can refer to the framework as a heuristic for checking whether their interventions adequately account for the influence of biophysical and social systems, the need for both specific and general capacity, and the potential for capacity to be differentiated across different people. Similarly, policy-makers may refer to the framework when developing adaptation strategies for rural water services to ensure that they do not neglect the above important elements of the capacity to respond to climate change disturbances.

Further theoretical and empirical research is needed to strengthen elements of the framework, especially in the context of community-managed water services. The interactions between specific and general capacities, and between capacity to respond at the system level and a sub-system level, are still relatively weakly theorized. Meanwhile, the general capacity of community-managed water services to respond to climate disturbances is under-researched relative to specific capacity. More engagement from the WASH sector with contextual vulnerability and SES resilience theory-practice is needed to produce empirical evidence of how general capacity is built in this context. Operationalization of the framework, through the development of methodologies for assessing the different framework elements and real-world testing on water services, is also needed.

Our framework focuses on maintaining community-managed water services in the face of climate disturbances, but this will not always be the goal of the stakeholders. Many communities in developing countries do not have access to sufficient amounts of safe drinking water to maintain in the first place. There also may be situations where water stakeholders do not want to maintain their current water service but instead transform it entirely into something more desirable (e.g. to a utility-managed water service). In these cases, application of this framework may not be appropriate. Thus, it is important to consult with stakeholders on what are their water access goals in relation to climate change before seeking to apply the framework.

Disclosure statement

No potential conflict of interest was reported by the authors.

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